

NASA Hypersonic Propulsion – Overview of Progress from 1995 to 2005

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Extended Abstract

Hypersonic propulsion work supported by the United States National Aeronautics and Space Administration had a primary focus on Space Transportation during the period from 1995 to 2005. The framework for these advances was established by policy and pursued with substantial funding. Many noteworthy advances were made, highlighted by the pinnacle flights of the X-43. This paper reviews and summarizes the programs and accomplishments of this era. The accomplishments are compared to the goals and objectives to lend an overarching perspective to what was achieved.

At least dating back to the early days of the Space Shuttle program, NASA has had the objective of reducing the cost of access to space and concurrently improving safety and reliability. National Space Transportation Policy in 1994 coupled with a base of prior programs such as the National Aerospace Plane and the need to look beyond the Space Shuttle program set the stage for NASA to pursue Space Transportation Advances. Programs defined to pursue the advances represented a broad approach addressing classical rocket propulsion as well as airbreathing propulsion in various combinations and forms. The resulting portfolio of activities included systems analysis and design studies, discipline research and technology, component technology development, propulsion system ground test demonstration and flight demonstration.

The types of propulsion systems that were pursued by these programs included classical rocket engines, “aerospike” rocket engines, high performance rocket engines, scram jets, rocket based combined cycles, and turbine based combined cycles. Vehicle architectures included single and two stage vehicles. Either single types of propulsion systems or combinations of the basic propulsion types were applied to both single and two stage vehicle design concepts. Some of the propulsion system design concepts were built and tested at full scale, large scale and small scale. Many flight demonstrators were conceptually defined, fewer designed and some built and one flown to demonstrate several technical advancements including propulsion. The X-43 flights were a culmination of these efforts for airbreathing propulsion.

During the course of that period, there was a balance of funding and emphasis toward rocket propulsion but still very substantial airbreathing propulsion effort. The broad objectives of these programs were to both advance and test the state of the art so as to provide a basis for options to be pursued for broad space transportation needs, most importantly focused on crew carrying capability. NASA cooperated with the Department of Defense in planning and implementation of these programs to make efficient use of objectives and capabilities where appropriate. Much of the work was conducted in industry and academia as well as Government laboratories. Many test articles and data-bases now exist as a result of this work. At the conclusion of the period, the body of work made it clear that continued research and technology development was warranted, because although not ready for a NASA system development decision, results continued to support the promise of air-breathing propulsion for access to space.

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Overview of Progress From 1995 to 2005

ISABE 2007
Beijing, China

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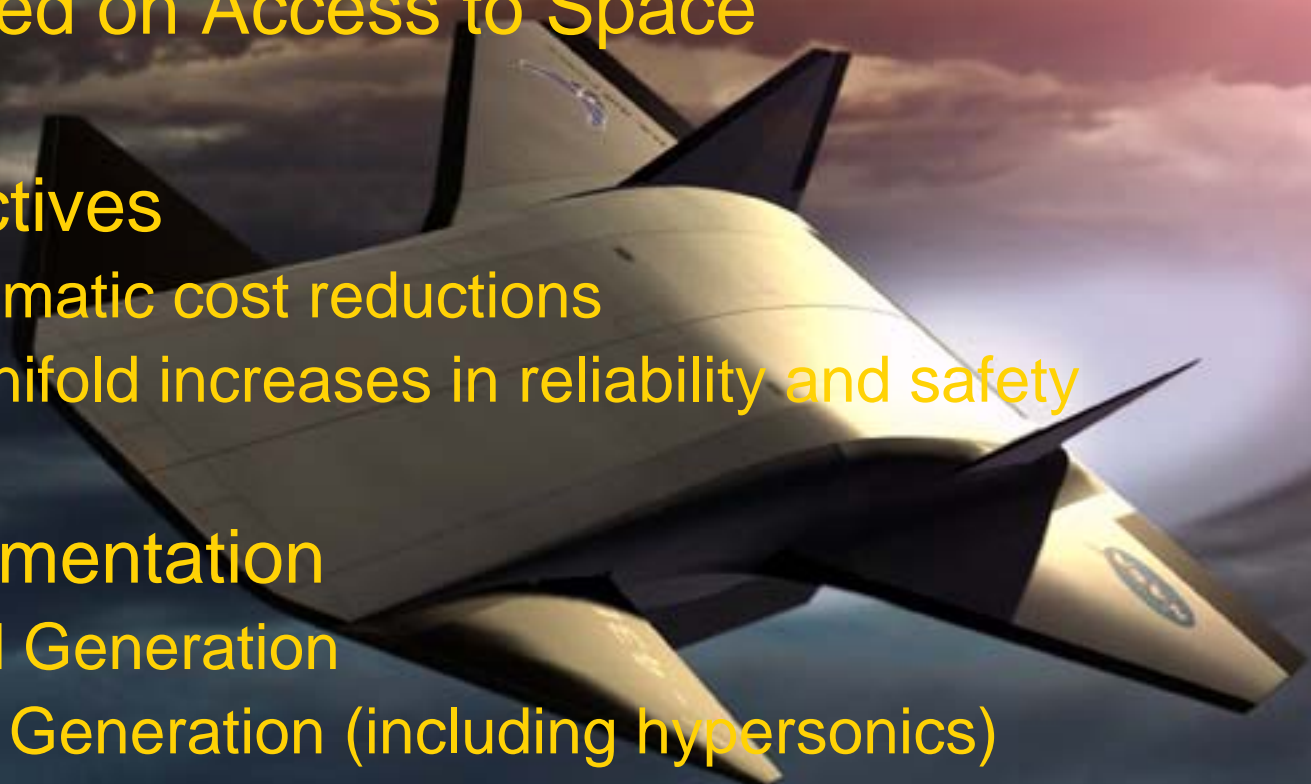
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Introduction

- NASA Hypersonic Investments 1995-2005 focused on Access to Space
- Objectives
 - Dramatic cost reductions
 - Manifold increases in reliability and safety
- Implementation
 - 2nd Generation
 - 3rd Generation (including hypersonics)



NGLT
NEXT GENERATION LAUNCH TECHNOLOGY

*Safe
Reliable
Affordable*



NASA's New Integrated Space Transportation Plan (ISTP)

*Space Shuttle Life
Extension Upgrades*

Orbital Space Plane (OSP)

- ISS Crew Rescue by 2010
- ISS Crew Transfer by 2012

SLI
SPACE LAUNCH INITIATIVE

**Next Generation Launch
Technology (NGLT)**

- Enabling Future National Launch Capabilities





Advanced Space Transportation Program

Large 3rd Generation RLV Design Space



Horizontal Take-Off SSTO



Vertical Take-Off SSTO

- Over 30 concepts (primarily using airbreathing propulsion)
- Selected by aerospace community (NASA, DOD, Industry)
- Probabilistic systems analysis for key technologies



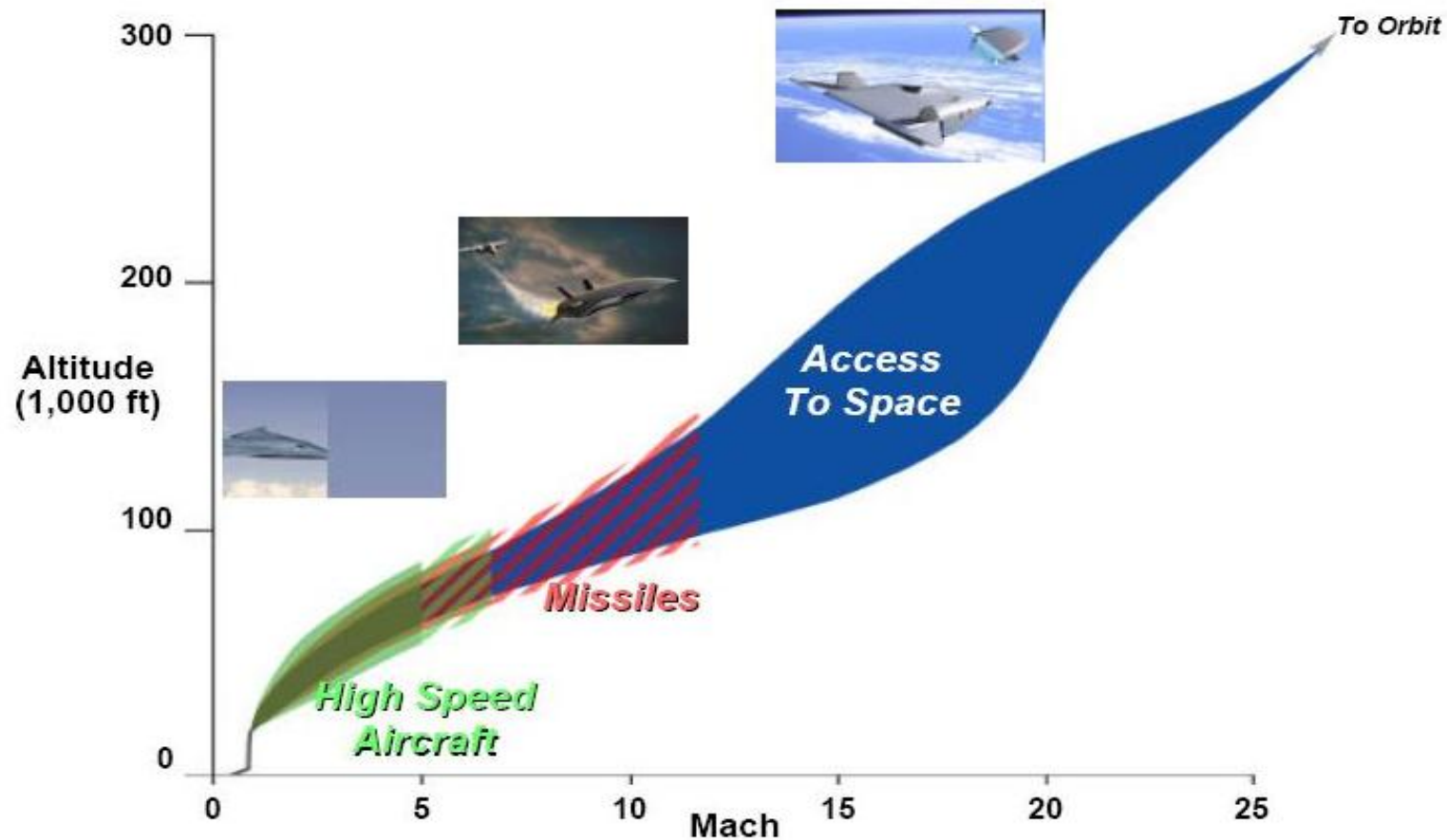
Horizontal Take-Off TSTO



Vertical Take-Off TSTO

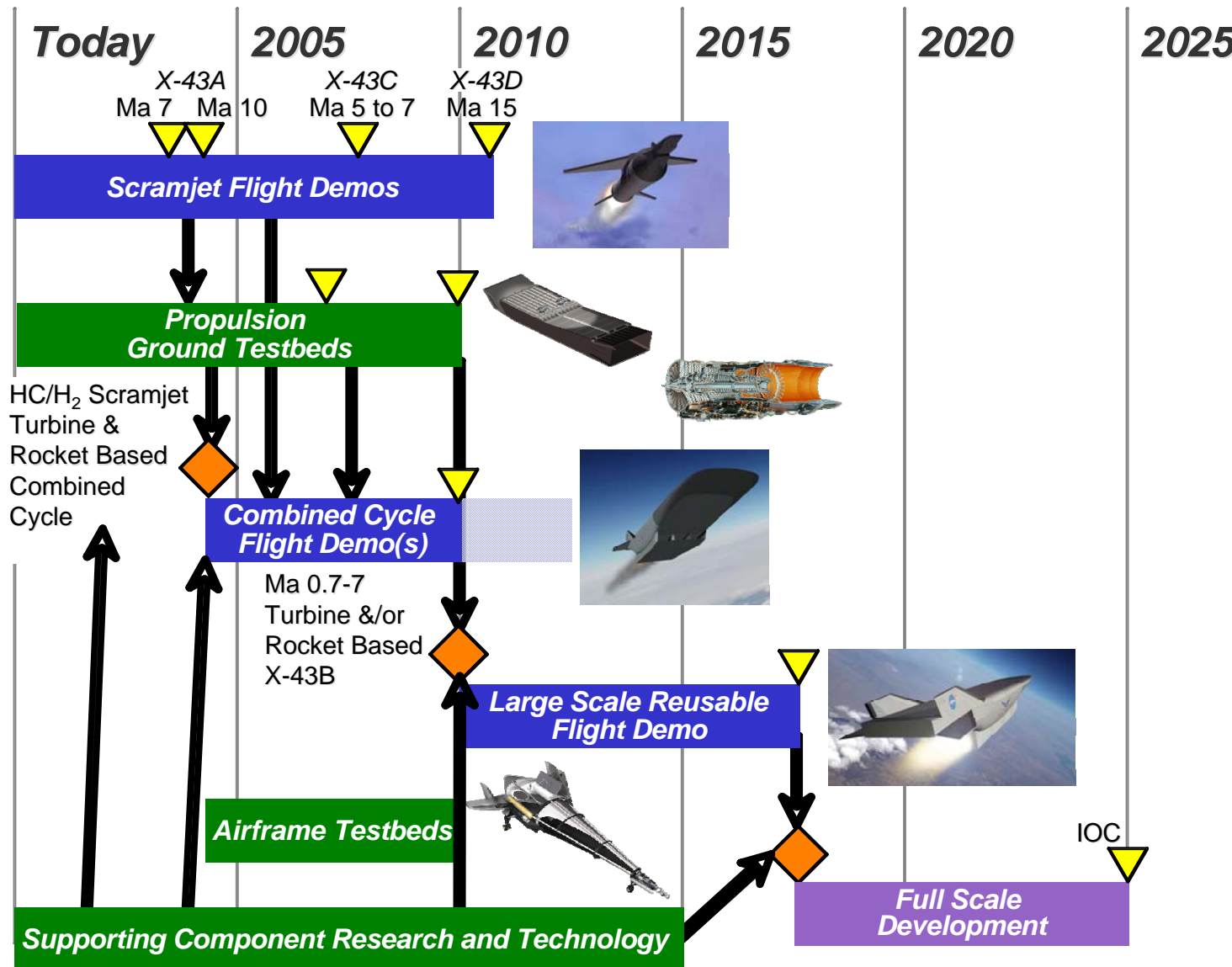
Representative Flight Corridors

Air Breathing Hypersonic Flight



Air Breathing Hypersonics

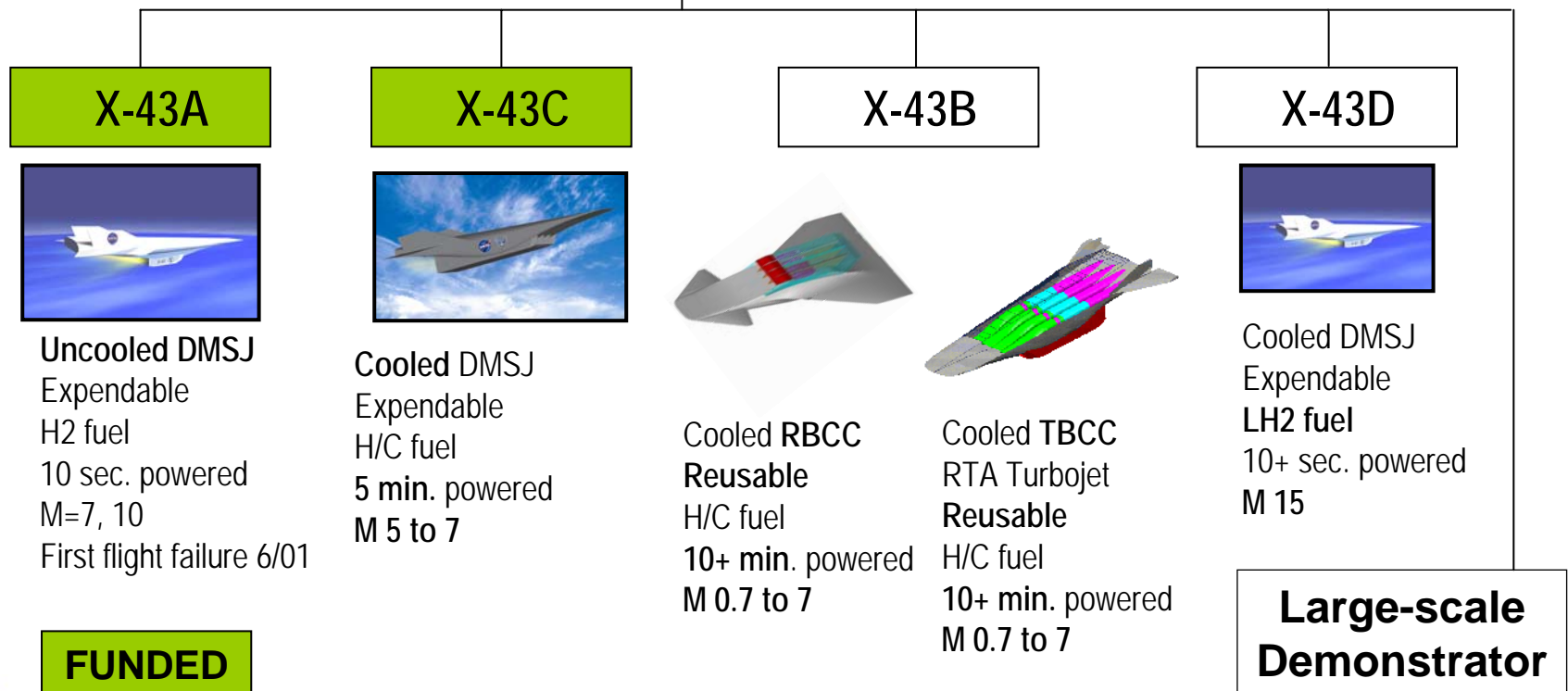
Access to Space Roadmap





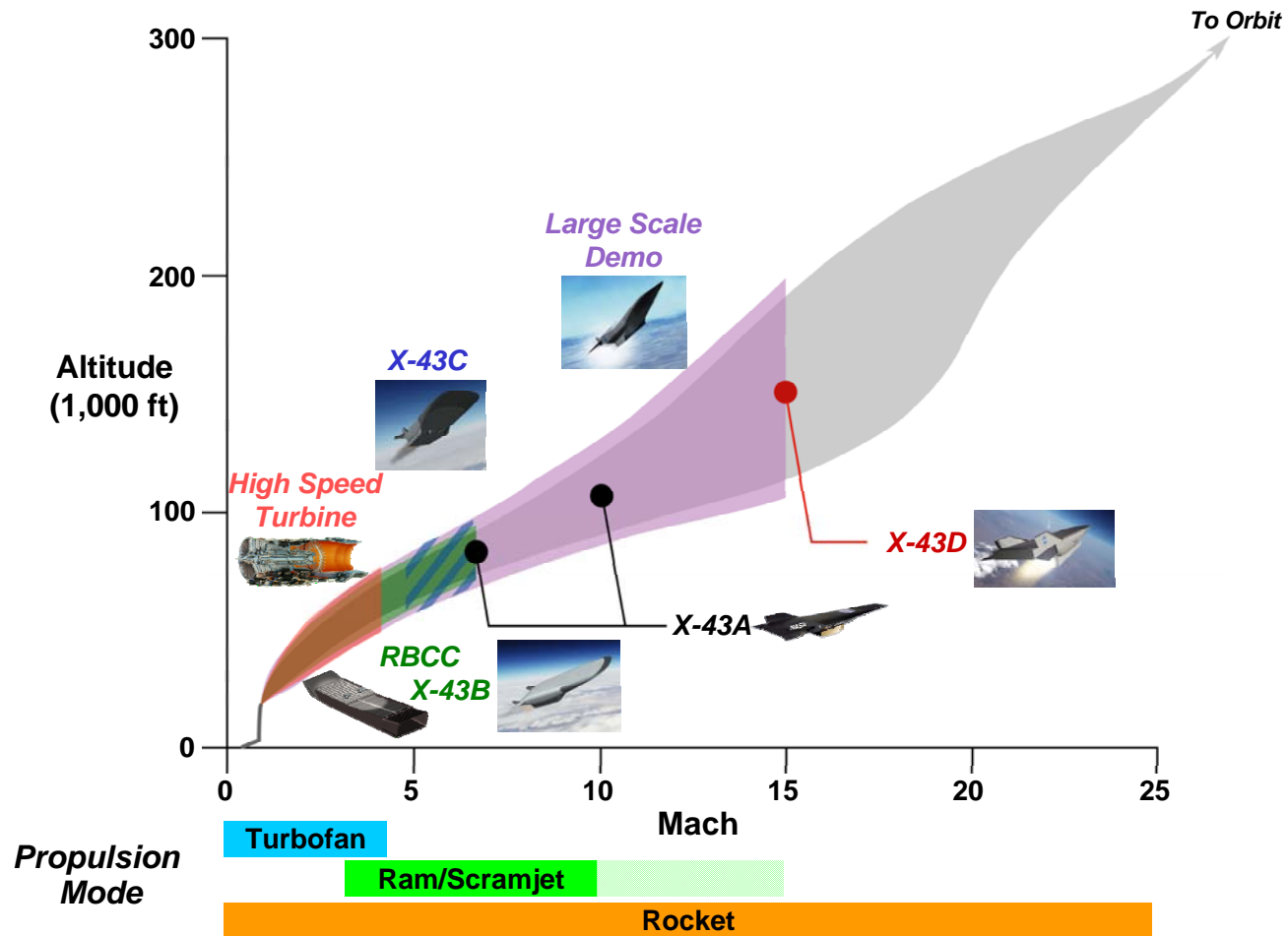
NASA HYPERSONIC FLIGHT DEMONSTRATION PROJECTS

Hyper-X and ASTP Flight Demonstrators



Incremental development leading to 2025 IOC

Demonstrator Application To Airbreathing Corridor



Enabling “Firsts” in Space Launch Technology

Booster Engine Prototype



- ◆ Highly reliable hydrocarbon fueled rocket booster engine
- ◆ High reliability, long life hydrogen rocket engines

Auxiliary Propulsion



- ◆ Non-toxic propellants for orbital propulsion

Vehicle Research and Technology



- ◆ Airframes capable of containing cryogenic propellants and reentering the Earth's atmosphere
- ◆ Durable high temperature thermal protection systems
- ◆ An intelligent, autonomous “all electric” launch system

Propulsion Research & Technology



- ◆ Long life, lightweight high temperature materials, seals and components

X-43A and C



- ◆ 1st controlled flight of a vehicle powered by a scramjet from Mach 5 - 7 and 10

Revolutionary Turbine Accelerator



- ◆ Lightweight, long life jet engines capable of flight at Mach 4

Accomplishments

- ◆ Analytical Methods
- ◆ Systems Analysis and concept exploration
- ◆ Supporting Technologies
 - ◆ High Temperature materials and structures
 - ◆ Aerosciences
- ◆ Components
- ◆ Aerodynamic Database



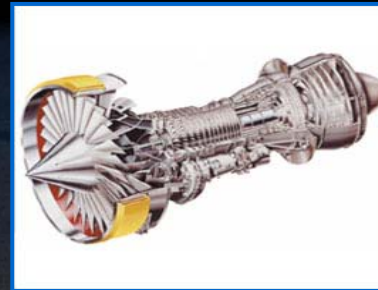
Measuring Our Progress



X-43A



X-43C



**Turbine Based
Combined Cycle**



**Rocket Based
Combined Cycle**

Redesign
completed

Concept Design and
System Requirements
Complete

2002

Awarded Mach 4
demonstrator engine
contract to GE Aircraft
Engines

Awarded Contract to Aerojet,
Pratt and Whitney,
Rocketdyne
Consortium. System
Requirements Complete

2003

2nd Flight - Mach 7

Award of Demonstrator
and Launch Vehicle
Contracts

Complete Project
Readiness Review and
Definition of System
Requirements.

Complete concept design

2004

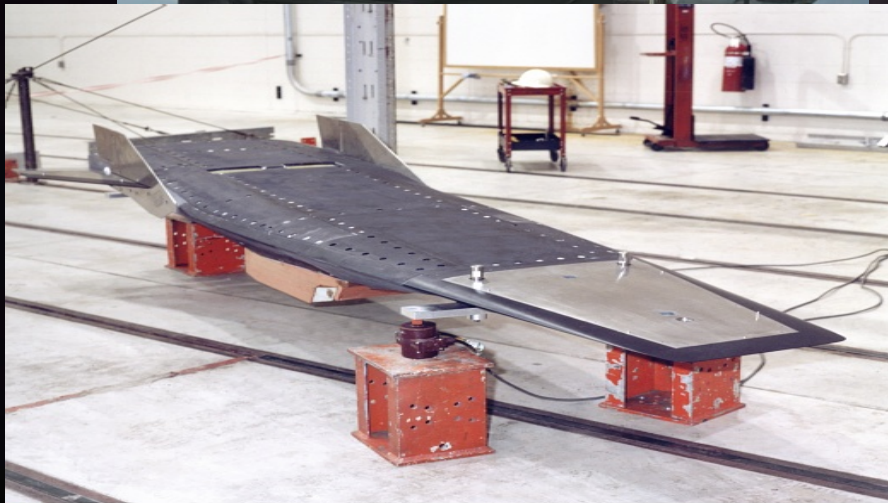
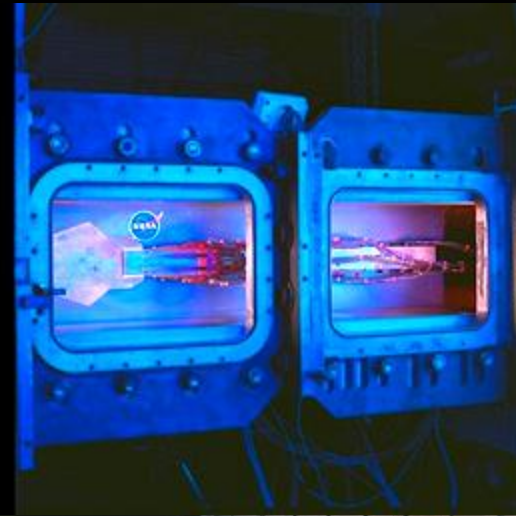
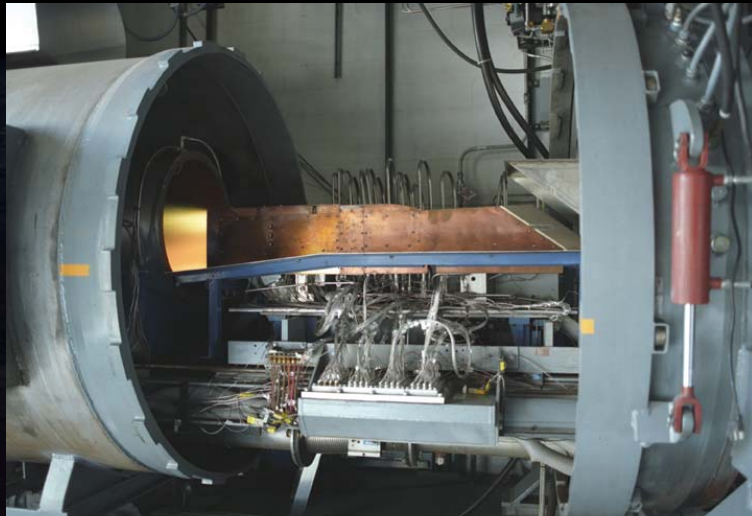
3rd Flight - Mach 10

Complete Design of the
Multimodule Flowpath
Propulsion Demonstrator

Complete design of
Mach 2.5 fan

Complete the preliminary
design of the ground test
engine

Some Examples



NASA Dryden Flight Research Center Photo Collection
<http://www.dfrc.nasa.gov/gallery/photo/index.html>
NASA Photo: EC99-45265-11 Date: December 1999 Photo by: Tom Tschida
X-43A Vehicle During Ground Testing



NASA Dryden Flight Research Center Photo Collection
<http://www.dfrc.nasa.gov/Gallery/Photo/index.html>
NASA Photo: ED04-0082-2
Mach 7 wind tunnel test of the full-scale X-43A model with spare flight engine in Langley's 8-Foot High Temperature Tunnel.



NASA Dryden Flight Research Center Photo Collection
<http://www.dfrc.nasa.gov/Gallery/Photo/index.html>

NASA Photo: EC04-0325-23 Date: November 16, 2004 Photo By: Carla Thomas

NASA's B-52B launch aircraft cruises to a test range over the Pacific Ocean carrying the third X-43A vehicle attached to a Pegasus rocket on November 16, 2004.

Summary- NASA Hypersonics 1995-2005

- ◆ Focus on ambitious safety and cost objectives for access to space
- ◆ Substantial progress on variety of fronts
- ◆ Preferential direction identified / Achievability not known



- ◆ Pinnacle reached with flights of X-43
- ◆ At end of period NASA investments reduced
 - ◆ Exploration focus
 - ◆ Remaining technical challenges